Development Patterns and Fire Suppression

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A relationship exists between the pattern of residential development and the potential costs and losses from wildfire in the immediate area. It arises through interactions involving risk, hazard, institutional response and asset exposure. Different development patterns can be linked to impacts on fire service workload. Probable fire scenarios can assist fire managers in offering sound advice to developers and planning staffs to limit potential losses. This paper presents a framework for reflecting these observations.

The framework suggests the following impacts of three typical development patterns (uniform two-acre parcels, mixed-size dispersed, and mixed-size clustered) on the four dimensions of the fire problem (risk, hazard, response and exposure).

Table 1 below presents fire impact factors and expected costs and losses by development pattern. It assumes development occurs in a high hazard area and fires occur under severe fire weather. Cell entries indicate influence of the development pattern on the factor. Increases in risk, hazard, suppression difficulty, and exposure tend to increase expected costs and losses. The top mark indicates relative change in fire impacts factor for initial attack within development; the lower mark indicates relative change in factor given an established fire outside the area impinging on the development. Minus signs indicate a reduction, plus signs an increase, and zeros indicate no change or intermediate affect on the factor. N/A indicates “not applicable”.

Table 1

Factor	2-acre	Mixed-dispersed	Mixed-clustered
Risk	+ N/A	- N/A	- N/A
Hazard	- +	+ +	0 -
Suppression Difficulty	- -	+ +	0 0
Exposure	- +	+ 0	+ -
Expected Costs and Losses	- 0	+ +	0 -

Taken together, the various factors indicate that the least desirable pattern is the mixed-dispersed arrangement of varying lot sizes. This kind of development intersperses a variety of fire environments, increases the edge between them, and makes both pre-fire and suppression activities more difficult. At the other end of the spectrum, a mixed-clustered design offers opportunities to reduce ignitions and decrease fuel continuity, while exposing fewer houses to fire. The uniform two-acre pattern offers some benefit by reducing hazard and improving access. However, independent of mitigation actions, the greater number of houses in a two-acre pattern adds substantially to exposure, thus outweighing the benefits in any high fire threat environment in all but initial attack fire scenarios.

Fire Impacts Equation

Risk + Hazard + Suppression Difficulty + Asset Exposure = Fire Impacts

Where:

Risk is the likelihood of an ignition (fires per unit area per unit time);

Hazard relates to potential fire behavior, the result of fuel, topography and weather;

Suppression Difficulty incorporates characteristics affecting fire suppression effectiveness; response times, tactics, infrastructure, and pre-fire planning such as ordinances, closures, etc., should all be considered;

Asset Exposure encompasses all resources that are potentially affected by wildfire, including public safety, natural resources, and improvements (e.g., homes). This analysis assumes no resource benefits from wildfire and equates exposure with a combination of public safety and property.

In the following analysis, we will employ this model for impacts by making assumptions regarding changes that are likely, given the development pattern in question, and placing a particular set of adverse fire scenarios against it.

Rezoning a Large Development

What would happen to fire starts, fire suppression, and expected costs and losses if the minimum parcel size were changed to accommodate 4-, 8-, 20- and 40-acre lots within an area currently zoned for two-acre parcels with a buildout population of 54,000 people? Unknown are the number of lots of each size, possible changes in overall land area, spatial pattern of lots relative to their size, or reductions in the number of people per lot. We assume that the development encompasses a fixed area, and that the changes in lot size reduce the total number of homes in the development.

While the following analysis reflects both fire science and fire service practices, the particulars of any given scenario should guide fire management policy. Actual site characteristics, including wildland fuel structure and arrangement, topography, weather, current and future suppression capacity, and development pattern (landscape and structural composition, density pattern, road networks, etc.) will affect fire occurrence, fire behavior, and potential workload and damages. Additionally, local governmental ordinances regarding fire prevention may influence the outcome.

The analysis posits three general development patterns each, over an area of approximately 20,000 acres:

1. Baseline as proposed, with individual lots of two acres (Figure 1);

2. A clustered mixture of lot sizes ranging from two to 40 acres, where lots of similar sizes are located near one another (mixed-clustered) (Figure 2); and

3. A dispersed or random pattern of variable lot sizes scattered throughout the development (mixed-dispersed) (Figure 3).

Figure 1.

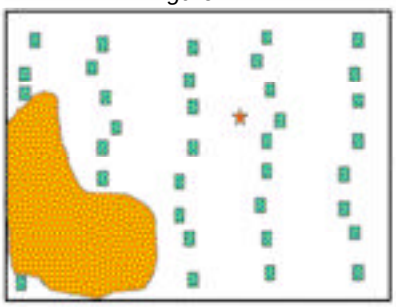


Figure 2.

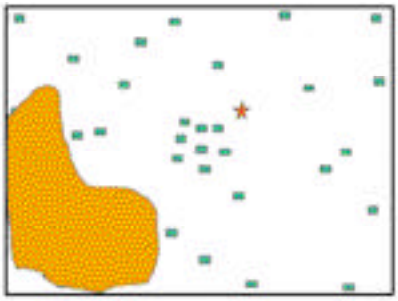
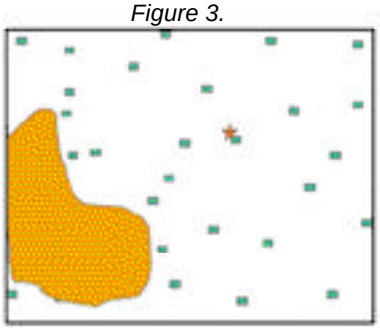


Figure 3.



House

Initial Attack Fire

Extended Attack Fire

Against these alternative landscapes we can envision two relevant fire scenarios:

- A fire originating within the development, thus raising issues of initial attack and containment.
- An established fire of large size either within the development area or impinging on its perimeter from adjacent wildlands, thus raising issues related to extended attack.

We assess how each combination of development pattern and fire scenario affects each of the fire impacts components. We make specific comparisons between development patterns and fire scenarios, and aggregate the components together into an assessment of potential costs and losses.

Risk

Population density and human-caused ignitions often are correlated in rural intermix situations where homes are interspersed into a matrix of largely continuous wildland fuels. All else being equal, the two mixed development patterns will result in fewer houses, fewer people, and consequently fewer ignitions than compared to the dense uniform two-acre pattern (Table 1).

The risk from fires originating outside the development depends on the potential ignition sources and fuel characteristics present *outside* the development area—probability of ignition outside the development, general flammability, fuel moistures, etc.— that would spread the fire toward and into the development. Since these features are unchanged by the happenings within the development, the basic

relationship between risk and development pattern reported in Table 1 concerns only fire starts within the development itself.

Hazard

The two-acre pattern would create fuelscapes that are both more broken (discontinuous and mixed) and more managed than in patterns with larger parcels. A more developed road system required to service the denser development further decreases fuel continuity. From an initial attack perspective, the two-acre pattern presents the lowest hazard. However, if the fire has become established, and has broad fire fronts impinging on a more densely settled area, the existence of discontinuous isolated structures creates additional problems from increased spot fires originating from the houses themselves. That is, this scenario implicates structures as the primary hazard element largely due to firebrands from burning houses becoming the principal mechanism for both fire spread and additional structure ignition. While defensible space designs may reduce the likelihood of structural ignition from the flame front, they do not mitigate brand ignitions as effectively. The two-acre development pattern that helps in the case of a small initial attack fire becomes a liability when an established fire starts to involve structures. Consequently, the assessment of hazard in the dense development pattern relates largely to the fire scenario. When the fire is small, hazard is low. But, if the fire is large, hazard is high (Table 1).

Developments with mixed parcel sizes will leave more continuous vegetation fuels, with the dispersed housing pattern creating the most continuous fuel complex with the highest hazard (Table 1). Larger lots will have less managed fuels, and the benefits from small lots will be lost by scattering these parcels within a matrix of continuous fuels. If we assume that the two mixed patterns have the same housing density, the clustered pattern at least concentrates the smaller parcels together to maximize the benefits of managed lots and increased discontinuity of fuels. These benefits regarding hazard are applicable to both small, initial attack fires as well as established, extended attack fires (Table 1).

As has been borne out in most large loss urban fires, firebrands not only drive larger perimeter increase, they also can lead to structural involvement in parcels with excellent defensible space. Thus, when confronted with an established fire, the two-acre arrangement and the mixed-dispersed arrangement would present higher likelihood for structural ignition, thus posing greater hazard than the mixed-clustered arrangement (Table 1).

Suppression Difficulty

For initial attack fires within the development, the two-acre pattern increases fire service access, making suppression more efficient than either of the mixed-parcel arrangements (Table 1). While both the mixed-parcel patterns present fewer homes to impede wildland fire containment, the clustered pattern still localizes access to greater numbers of assets that may need protection. Additionally, concentrated areas of uniform lots may cause increased infrastructure designed to mitigate fire loss (e.g., hydrant locations). The dispersed pattern loses all benefits of both large and small lots, creating a diverse set of

initial attack conditions where small fires can spread rapidly and initial attack may require immediate structure protection (Table 1).

For extended attack fires, the relationship between development pattern and institutional response not only involves access and infrastructure but also decisions regarding tactics. The dense two-acre parcel pattern offers a uniform tactical environment within which the fire service can mount a coherent plan of attack. However, different lot sizes require different mixes of structure protection and perimeter containment, and therefore both mixed patterns render more difficult decisions on deployment of tactics. If the mixed parcels are clustered, these decisions become somewhat easier as the tactical environment resolves into two types: housing clusters and wildland perimeter containment. The mixed-dispersed pattern creates many environments, making each tactical decision unique. Decisions become difficult as key information regarding fire position, and which homes are burning, is hard to come by. Institutional response on large fires appears best in the two-acre case, intermediate in the mixed-clustered arrangement, and worst in the mixed-dispersed pattern (Table 1).

Asset Exposure

Exposure of assets susceptible to damage or loss from wildfire increases with the amount of developed "edge" adjacent to vegetation capable of spreading fire. Development planning can reduce exposure by actions such as: (1) reducing the edge-to-area ratio of the entire development; (2) incorporating managed greenbelts in development plans to break up the continuity of flammable vegetation; and (3) planting low flammability ornamental vegetation. Roads in developed areas may also function as fuel breaks and as staging areas for suppression resources.

While the two-acre pattern would yield the greatest number of homes, it probably also offers the greatest capacity for Fire Safe measures designed to mitigate losses. Localized defensible space and desirable building materials tend to create buffers where the asset exposure goes down as a function of area of treatment (i.e., more homes), thus effectively reducing the amount of edge to area of structure development. These features increase the collective protection of the development by keeping small fires small. Once a fire has a large front with structure involvement, however, the simple fact of more houses increases exposure to the threats coming from extended attack fires—rapid increases in size and burning brands directly igniting combustible structure materials. Thus, while best for initial attack exposure, the two-acre lots have the highest exposure for big fires, the clustered parcel pattern can exploit these virtues in some localized, albeit smaller, areas (Table 1).

While denser arrangements tend to increase loss potential for large, established fires, lower density arrangements with greater distance between structures reduce exposure of assets and offer greater tactical options to limit significant housing loss. However, large areas of continuous wildland fuels with randomly scattered houses increases the relative edge of wildland and structural fuels. This increase in edge ratio raises the chance of both rapid perimeter increase and structure involvement. In contrast, clustered

patterns can be designed to reduce edge, limiting fire size growth to low density areas and increasing defensible space for clustered lots. For example, a clustered pattern involving a concentric design—denser Fire Safe compliant lots in the middle and larger parcels outside with a fuel reduction zone along the perimeter of the development benefiting both densities—can be realized, resulting in lower exposure than the two-acre and mixed-dispersed patterns (Table 1).

Expected Costs and Losses

Table 1 portrays the effect of each development pattern on the fire impact factors along with their cumulative impact on costs and losses.

The **mixed-dispersed** pattern presents the greatest probability for large-loss fires. It intersperses a variety of fire environments, increasing the edge between them, and makes both pre-fire and suppression activities difficult. The only area where the mixed-dispersed pattern appears favorable concerns lower exposure to extended attack fires, but even then it is not lower than the mixed-clustered design.

The **mixed-clustered** design offers the ability to take into account specific localized characteristics designed to reduce ignitions, decrease fuel continuity, and facilitate rapid tactical decisions regarding perimeter containment and structure protection, while still having fewer structures lost than in the uniform two-acre parcel arrangement.

The dense **two-acre** arrangement does offer some degree of benefit in terms of reduced hazard, increased access, and mitigation infrastructure, as well as a uniform fire environment from which to base tactical decisions. However, these benefits would tend to apply more to an initial attack fire. Once extended attack has occurred, structure involvement is likely, and fire behavior and the high asset exposure would drive up expected costs and losses.

While simple numbers of assets in the dense arrangement poses high exposure, improved fuel and access conditions would lead to lower losses than for the mixed-dispersed pattern. Very large-loss urban fires usually have a mixed-interface scenario, where both rapidly spreading vegetation fires as well as significant and dispersed structure protection diverts significant resources. In contrast, either of the uniform density patterns would tend to push a fire toward structure protection or wildland fire containment, but not both. In dispersed mixed-interface developments, the landscape management of the development takes on a clearly variable nature—all presenting unique problems for firefighters—confounding a rational fire strategy.